	# FIRA Challenge - Autonomous Cars # Laws of the Game (Pro)

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Abstract

The focus of the FIRA Autonomous Cars competition is encouraging researchers to develop self-driving cars. In FIRA Autonomous Cars, two environments are designed for cars to compete against each other. The first environment is a racing circuit and the second one is an urban environment. Each environment has its own score and the total score of competitors will be the sum of both scores.

[FAC-1] Rules of the Game

The RC Car (from now on inside this document will be called car) used for this competition should be electrically powered. Fuel-based cars cannot participate in this competition. Please remember that your car has to abide by the following limits to be able to participate in the competition:

- Allowed Length Range : 300mm - 550mm
- Allowed Width Range: 150mm - 350mm
- Maximum Height: 450mm
- Electrically powered

Keep in mind that the car should have the Ackerman steering system, Note that two axis systems are also allowed.

Both 4WD and 2WD cars are allowed for the competition and cars will be quarantine minutes before each group run. Cars used for this competition should have 4 wheels and

Ackerman steering mechanism. The picture below shows an example of acceptable cars with the Ackerman steering mechanism.

Please consider that infrared line follower sensors are not allowed. For general specifications relevant to all FIRA events (e.g., playing field, lighting, and responsibility of the referees) please refer to General - FIRA Laws of the Game.

It is also important to note that each team can only use one car or platform, and although it's illegal to change the platform it is permissible to modify the car components for repair.

[FAC-2]: Game Structure

There are two stages in the competition, preliminary and final. Depending on an achieved score in the preliminary stage, some teams will be qualified for the final stage. Achieved scores during the preliminary stage will be reset to zero for the final stage. The order of participation in a stage is decided by a draw, a day before the start of the competition. Teams that are not present during the draw, will start the stage first, using another draw by present teams.

This competition consisted of two-parts, each part has its own scoring model and the total score will be the sum of the scores each team has obtained in both parts. The first part is called "Autonomous Race" and in this part, each car has to complete a race track autonomously one or more times depending on the stage. The second part is called "Autonomous Urban Driving" and in this part, each car should complete the specified task such as navigation according to road signs. Both parts are introduced in more detail in the next sections of this document.

[FAC-3]: Autonomous Race

In the race part of the competition, each car has to do some laps of a race track completely autonomous. There are multiple checkpoints inside the track and cars have to cross them while navigating through the track. Each missed checkpoint will result in a penalty. Depending on the stage, some obstacles might be placed inside the track and cars have to avoid them.

During this part of the competition, each team has a specific amount of time and during this time they have 5 runs. The maximum score of each run will be considered as the score of this part. The track will have a width of 50cm ± 10% for this section. **There is at least one turn with the outer turning radius of 1.5m ± 10% , your car should be able to turn in such conditions.**

The image below shows an example of a race track :
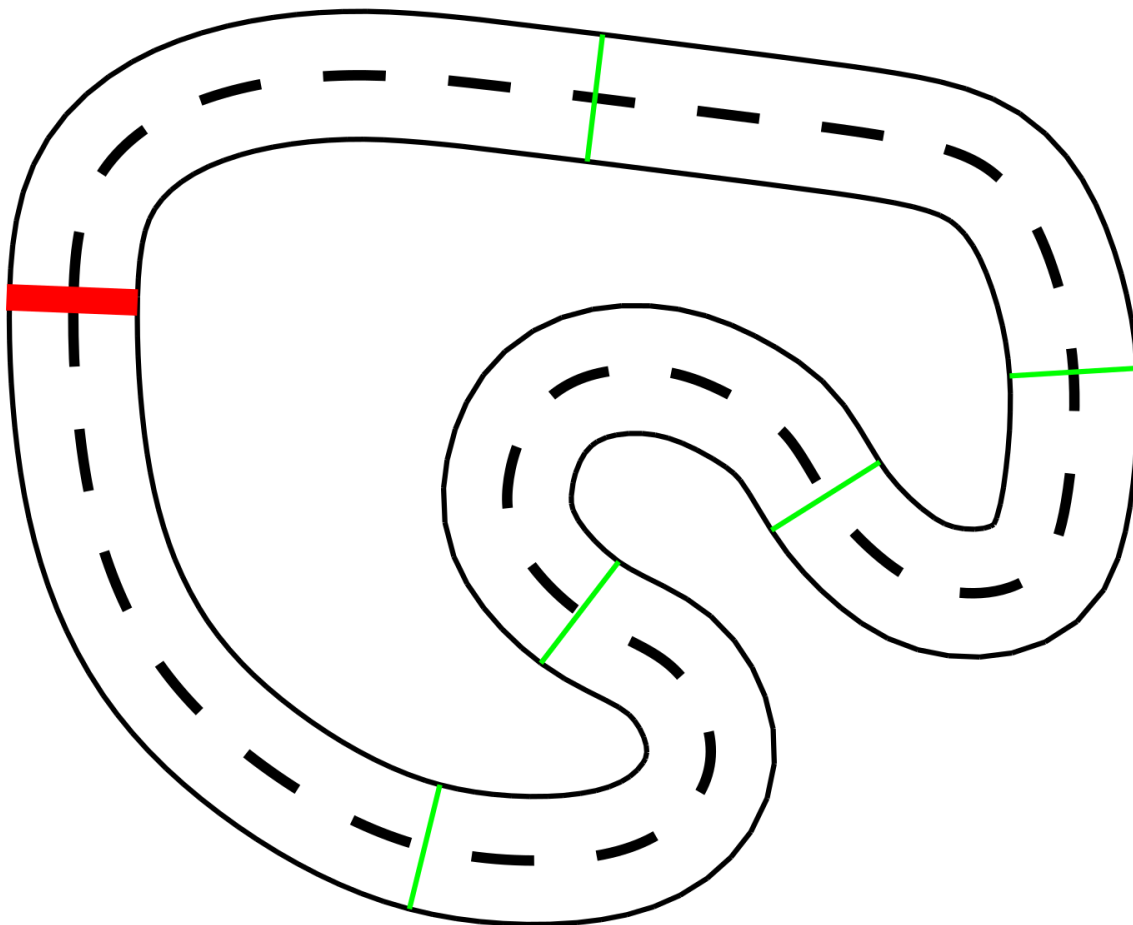
As shown in the image, the **track will be drawn on the ground using two white or black continuous sidelines and one dashed lane marking of the same color marking the middle of the track.**

The color of markings will be selected according to the color of the arena floor thus teams should be able to work with both colors. The checkpoints are shown in green and the start/finish line is shown in red. Checkpoints do not necessarily have any marking and the picture is just for demonstration. The start/finish line will be marked using a different color than road markings but not necessarily red.

The markings width is at least 1cm and two dashed lines have a minimum space of 5cm between them. Depending on the stage, there might be some obstacles inside the track and cars have to avoid them. If cars hit any obstacle inside or outside the track, their current run will be considered as finished.

[FAC-4]: Autonomous Urban Driving

For this part of the competition, cars have to navigate autonomously through an urban environment. Cars will start from a starting point and have to navigate through streets using street signs, lane markings, zebra crossing and other information available to be used by vision sensors. There are checkpoints inside the streets and each checkpoint has specific points. Every incorrect decision made by the car will result in a penalty which is discussed in detail in the score section.

During this part of the competition, each team has a specific amount of time and during this time they have 3 runs. The maximum score of each run will be considered as the score of this part. The track width is 60cm ± 10% for this section.

A marker will be placed below each street sign which makes it easier to recognize the sign using vision sensors. Markers will be April Tags (36h11 family) with a size between 4cm x 4cm and 8cm x 8cm. The urban arena will look like the picture below (this is not the street map and is just for demonstration purpose) :
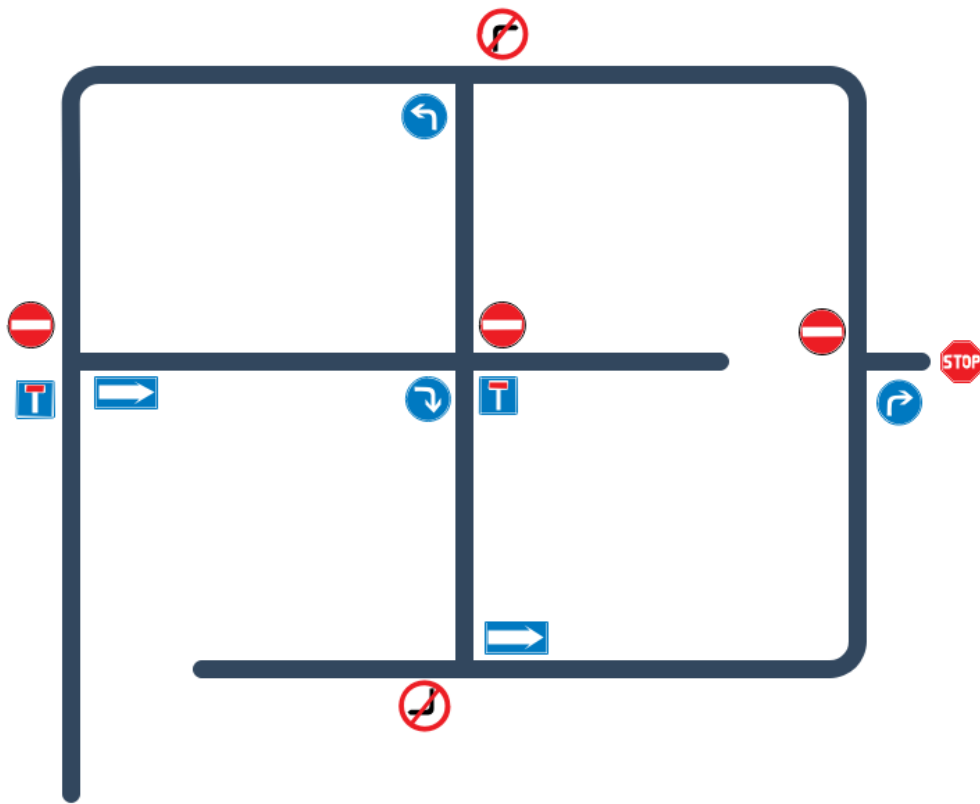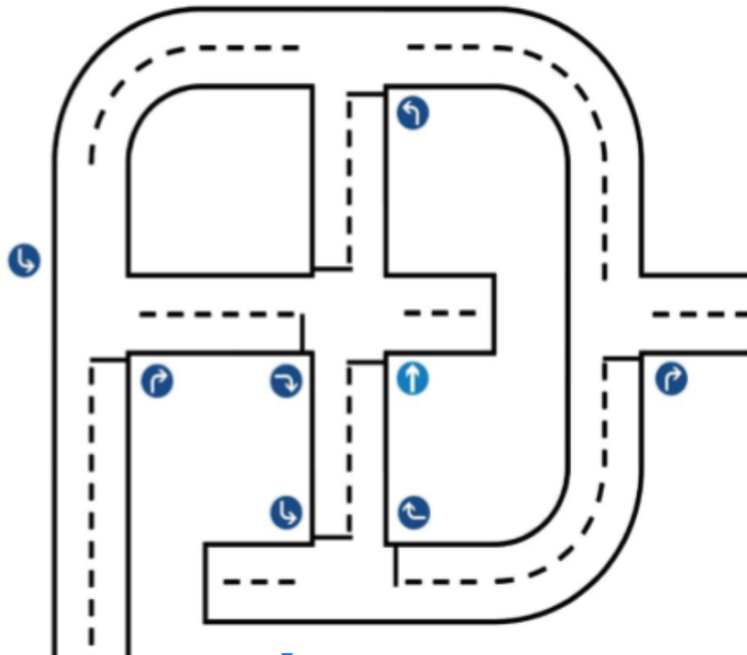
In the picture above, cars have to start from the bottom right and follow the street based on the street signs, reach the destination and stop where the stop sign is. There is at least one
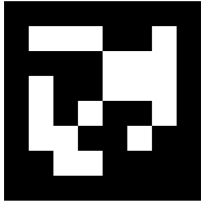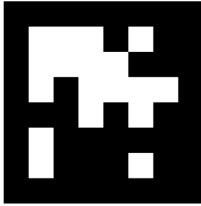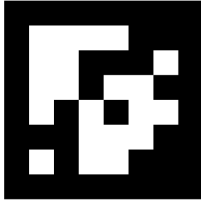
checkpoint between every two junctions. Every incorrect turn has a specific penalty and also the car has to move along the correct lane. Each street has one of the markings shown in the picture below :

The marking indicates a one-way street. Therefore the car can change lanes, but **the car must be on the right lane when passing a checkpoint**.

List of street signs is as below :

Sign Name	Sign Picture	Sign Marker	Car Decision
Ńo Entry			Should not enter the street which has this sign in the beginning of it.
Dead End			Should not enter the street which has this sign in the beginning of it.
Proceed Right			Should choose the road on the right of the junction.

Proceed Left			Should choose the road on the left of the junction.
Proceed Forward			Should proceed forward.
Stop			Should stop (this is the destination).

Cars also have to stop for at least 3 seconds before the zero crossings of each junction. Some penalty points will be considered if the car crosses the junction without any stop. The same rules of the previous part apply to width and type of road markings in this section. Depending on the stage, there might be some obstacles inside the streets. If cars hit any obstacle, their current run will be considered as finished.

There is a stop line about one centimeter before the zebra crossings of each junction that is vertically located by zebra crossings and cars should stop before this line.

[FAC-5]: Score Calculation

Each part of the competition has its own scoring model, scoring models are listed below.

[FAC-5-1]: Level of Autonomy

Cars have to do the missions completely autonomously. This can be done by using a computer onboard or offboard. A coefficient will be multiplied in the final score of teams based on their level of autonomy. This coefficient is defined as below :

Level of Autonomy	Ka (coefficient)
Offboard	0.5
Onboard	1

Each team has the choice of using the signs or the April Tags, but the scores are calculated according to the following table:

Level of Autonomy	Ka (coefficient)
April Tags	1
Signs	1.3

[FAC-5-2]: Autonomous Race Scoring Model

During the race part, a score will be calculated based on the total time. Total time is the sum of the time taken for the car to complete the track or pass some checkpoints and other penalties that will be added to total time depending on how well the car has followed the track autonomously. The penalties table is shown below :

Penalty Definition	Penalty Time
Skipped checkpoint (each)	$+ \, 0.5 * \dfrac{T_{stage}}{Number\ of\ all\ checkpoints}$ (s)
Parts fell (each)	$+ \, 0.2 * \dfrac{T_{stage}}{Number\ of\ all\ checkpoints}$ (s)

A score of this part is calculated using the following formula :

$$S_{AR} = (1 + \max\{ \frac{T_{stage} - T_{total}}{T_{stage}}, 0\}) * 35 * cp$$

The stage time (Tstage) is the amount of time each team has to do the race in each stage which will vary between preliminary and final stage. For example, if a team is given 200 seconds and can finish the competition in 100 seconds and not lose any checkpoints (for example, if it scores 14 checkpoints), it will receive 735 points.

[FAC-5-3]: Autonomous Urban Driving Scoring Model

In this part, cars have to start from a starting point and navigate in the streets according to the signs and reach the destination point. Each checkpoint reached by car has 60 points. The sum of these points minus the sum of the penalty points each car received during its navigation will be the score of this part. The penalty points table is shown below :

Penalty Definition	Penalty Points
No stop injunction	-10
The incorrect decision injunction	-30
Incorrect lane change (once between two junctions)	-20

[FAC-5-4]: Total Score

The total score is sum of the autonomous racing and autonomous urban driving scores:

$$S_T = S_{AR} + S_{AUD}$$

Notes :

- The finish line is considered a checkpoint.
- **The car needs to be completely inside the road and in the right lane while passing a checkpoint otherwise the checkpoint will be considered as a miss.**
- The scores of each part can not become negative.
- If the car hits an obstacle, the run is considered finished. If the car gets out of the road in an urban environment, it will be considered as a collision with the road barrier and run will be finished.
- The team leader can say "STOP" during the race at any time and the run will be considered as finished.

- Touching or taking control of the car without saying "STOP" will reset the run and no score would be calculated for that run.

These notes apply to both autonomous racing and autonomous urban driving.

[FAC-6]: Team Description Paper (TDP) and Video

Each team has to submit:
1. Team description paper (TDP)
2. Video from the performance of the car

You can find the **TDP** template inside the FIRA website (the preferred format is Springer LNCS format). The **TDP** should contain information about both hardware and software used in the car.

[FAC-7]: Rules Change

These rules may be changed by the technical committee at any time before the competition. Teams have to check these rules regularly to make sure they know about any changes made. The latest version of official FIRA Autonomous Cars rules is always available using this link.

There is also a rules book available for this league and the other leagues in FIRA RoboWorld Cup and Summit 2023, and the latest version can be accessed from here.

Last modified: May 27, 2023 (v1.2.4)